APPLICATION FOR UNITED STATES PATENT

in the name of

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Of

Align Technology, Inc.

For

Health-Care E-Commerce Systems and Methods

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Health-Care E-Commerce Systems and Methods

BACKGROUND

The Internet has become a significant medium for communication and commerce and has enabled millions of people to share information and conduct business electronically. The unique characteristics of the Internet such as its ability to provide enhanced communication, rich text, and graphic environment provide an ideal support for a wide variety of electronic commerce transactions. For example, a consumer can search, review, and extensively shop a number of competing chains in an instant. As such, consumers benefit by being able to obtain a good price relatively quickly and easily.

On-line retailers also benefit, since these retailers can carry a larger number of products at a lower cost and with greater merchandising flexibility without the physical constraints faced by traditional retailers. Additionally, they can assist the consumer's purchase decision by providing relevant information and enabling consumers to shop at their convenience by remaining open 24 hours a day, seven days a week. Online retailers can also provide personalized services and use direct marketing efforts based on information provided by customers.

As such, the Internet has evolved into a unique sales and marketing channel. The ubiquity and convenience of the Internet makes it ideal for dispensing information on certain topics that traditionally require visits to specialists. For example, certain consumers may be interested in products and services associated with orthodontics and dentofacial orthopedics that specializes in the diagnosis, prevention and treatment of dental and facial irregularities ("malocclusion" or "bad bite"). The orthodontic treatment process typically uses corrective appliances such as braces and/or other fixed or

removable appliances to bring the teeth, lips and jaws into proper alignment and to achieve a facial balance. The pervasiveness of the Internet makes it an ideal source for information relating to these products and services.

SUMMARY

In one aspect, a virtual health-care electronic commerce community includes a network to communicate information relating to the community; one or more patients coupled to the network; one or more treating professionals coupled to the network; and a server coupled to the network, the server storing data for each patient and performing patient data visualization in response to a user request.

Implementations of the above aspect may include one or more of the following. The treating professional can view one or more of the following patient data visualization over the network: a right buccal view; a left buccal view; a posterior view; an anterior view; a mandibular occlusal view; a maxillary occlusal view; an overjet view; a left distal molar view; a left lingual view; a lingual incisor view; a right lingual view; a right distal molar view; an upper jaw view; and a lower jaw view. The treating professionals can include dentists or orthodontists. One or more partners can be connected to the network. The partners can be a financing partner, a supplier, or a delivery company. The treating professionals can perform office management operations using the server. The office management operations include one or more of the following: patient scheduling, patient accounting, and claim processing. The patients and the treating professionals can access the server using browsers.

In another aspect, a method for performing dental-related electronic commerce includes transmitting teeth data associated a patient from a dental server to a treating professional computer over the Internet upon an authorized request; displaying a three-dimensional computer model of the teeth at the treating professional computer using a browser; allowing a treating professional to manipulate the three-dimensional computer model of the teeth using the browser; transmitting the computer model from the treating professional computer to the server; and generating an appliance to treat the patient based on the computer model of the teeth.

Implementations of the above aspect may include one or more of the following. The system can provide financing options for the patient using one or more financing partners. The system can offer an on-line shop geared to the patient's dental requirements. The system also allows a treating professional to manipulate the three-dimensional computer model of the teeth using the browser further comprises displaying a plurality of dental views.

A treating professional can manipulate the three-dimensional computer model of the teeth using the browser further comprises clicking on a tooth to adjust its position. The system can display x, y and z axis to allow the treating professional to adjust the position of the tooth. Supplemental services can also be offered to the patient, including teeth whitening services.

In another aspect, a server supports a health-care electronic commerce community with one or more patients and one or more service providers. The server includes a processor adapted to communicate with a network; a data storage device

coupled to the processor and adapted to store data for each patient; and software to communicate 3D patient data in response to a client request.

Implementations can include one or more of the following. A browser can receive the client request and transmitting the request to the server. The browser can use a viewer plug-in to visualize patient data in 3D. The providers can provide health-care service such as dentistry applications, cosmetic augmentation, hair-care enhancements, liposuction, plastic or reconstructive surgery.

Advantages of the system may include one or more of the following. The system supports a virtual community of dental patients, dentists, specialists such as orthodontists and oral surgeons, financial institutions, benefit providers and the providers of dental equipment or services. For treating professionals, such as dentists and orthodontists, the system provides a one-stop solution for planning patient treatments, managing communication with patients, storing patient records and sharing records with relevant persons outside the doctor's office. The system can act as the repository for the file notes and visual imagery (photographs, x-rays and virtual treatment plans) associated with the course of treatment. The doctors will control access to the centralized patient file. Various tools are provided to support the interpretation of information and the diagnostic process. For example, the system allows the doctors to retrieve, and analyze patient information and to simulate using two and three-dimensional visual imagery of the patient's teeth and other anatomical structures. The system supports visualization of the expected outcome of a particular course of treatment. Working together with the patient these images can enhance the patient's understanding of the benefits of treatment and act as a valuable selling tool for the doctor. The system also provides diagnostic decision-

support capabilities such as visualizing the placement of implantations, veneers and crowns before or after a course of treatment to straighten the teeth. The system provides an animated prediction of the suggested treatment that helps the patient and the doctor to visualize the pace of treatment. Using these tools, the doctor can easily and quickly view and/or edit the treatment plan. When doctor and patient choose the final treatment plan the system disseminates aspects of the plan and the relevant patient records to the appropriate members of the virtual community, thus reducing the cost and delay associated with tradition physical shipment of patient information. Aspects of the final treatment plan can be used to generate appliances used in the physical treatment. The information associated with the patient's treatment (visual images, virtual treatment plans, file notes and the like) are digitized and maintained in a central storage facility in a secure manner. Doctors and patients can have access to these files without the need to extract files and models from storage and with reduced risk of records being misplaced.

Administratively, the system allows the office to be managed more efficiently without requiring the treating professional to purchase and maintain special software. The system keeps track of all patients that need to be contacted for an appointment. Scheduling can be done automatically or can be customized to the office's preference and availability of treating professionals and supporting resources. Based on the appointments, the system can electronically mail (email) patients with reminders. Alternatively, the system can print reminder cards that can be mailed to patients reminding them of their appointment. The system can also automatically generate personalized correspondence to patients relating to data collected in the initial exam and

treatment recommendations. Moreover, the patient can review the proposed treatment with the treating professional anywhere.

The system also simplifies and streamlines the processing of insurance claims to produce an orderly flow of information. Insurance claims can flow through the treating professional's office from pre-authorization to continuation of treatment with a minimal amount of intervention. The system also provides accounting functions to check out patients, post charges, setup contracts, add comments to ledgers, post payments, adjust ledgers, and display all transactions applied to specific ledgers.

Moreover, the treating professionals can leverage the collective purchasing power of the system by ordering being able to order supplies required by patients directly through the system at a discount. These supplies can be directly shipped to the patients, thus avoiding overhead costs associated with handling the supplies. Further, information reviewed or generated by the treating professionals is provided through a secure on-line connection. Thus, the patient's privacy as well as the treating professional's sensitive office information is not compromised.

For patients, the system provides a broad array of dental-care resources that help consumers find answers to their critical dental questions and make informed purchasing decisions. The system also enables people to share their experiences and to support one another in managing their medical conditions. This is done through forums where Internet users with interests and concerns about their dental health can interact with each other, to interact in a community environment and to access content created by others. The system is convenient to use and provides informative shopping experience through which dental care services and dental-related products can be dispensed. Consumers can

access the system using an intuitive, easy-to-use shopping interface that is available 24 hours a day, seven days a week. Consumers can shop quickly and conveniently from anywhere Internet access is available. For example, a customer can store his or her dental history and other relevant dental information, as well as create personalized shopping lists for quick and easy reordering of his or her dental supplies.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a diagram of an exemplary environment supporting electronic commerce.

Fig. 2 is a diagram of a server to support electronic commerce.

Fig. 3 is a diagram of a web site on the server of Fig. 2.

Fig. 4 is a flowchart of a process for selecting dental services from a patient's perspective.

Fig. 5 is a flowchart of a first process for providing dental services from a treating professional's perspective.

Fig. 6 is a flowchart of a second process for providing dental services from a treating professional's perspective.

Fig. 7 is a flowchart of a process to render 3D views of a patient's teeth on a browser.

Fig. 8 is an exemplary output of the process of Fig. 7 using the browser.

Fig. 9 is a diagram of a system for manufacturing appliances.

Fig. 10 is a diagram illustrating a computer system to support the fabrication of appliances.

DESCRIPTION

Referring now to Fig. 1, an environment supporting a dental system 100 is shown. The system 100 communicates over a network 102 that can be a local area network or a wide area network such as the Internet.

One or more client computers 104-105 can be connected to the network 102. In one embodiment where the network 102 is the Internet, the client computers execute a suitable browser such as Navigator from Netscape, Inc. and Internet Explorer from Microsoft Corp. By clicking on the highlighted text (or specific graphic image), the user can jump from the current web page to a new web page address associated with the link--with the new page displayed on the screen. In this manner, the user can "surf the web" by clicking on an almost endless succession of links going to page after page all following a common thread as defined by the text or graphic component of the link label.

Through the network 102, the client computers 104-105 can access a dental server 106. The dental server 106 serves a web site, a portal, a vortal, or a content site for providing dental related information to interested parties such as dental patients, dentists, orthodontists, and others. When sensitive information is communicated through the dental server 106, such information is securely encrypted using Secure Sockets Layer (SSL) technology throughout the transaction. The server 106 can be a stand-alone computer or can be a server farm that can distribute processing and communications activity across a computer network so that no single device is overwhelmed. During load balancing, if one server is swamped with requests, excess requests are forwarded to another server with more capacity.

The network 102 connects the dental server 106 to one or more treating professional workstations 108-109. The workstations 108-109 allow treating professionals access to a plethora of services provided by the dental server 106 such as patient treatment and office management, among others. The dental server 106 stores information associated with patient history on-line in a secure manner. The server 106 also allows the treating professional to have a comprehensive view of the patient's treatment history at any time using a suitable browser, eliminating the need to pull treatment files or charts or to look for misfiled or lost charts. The dental server 106 also provides treating professionals with tools to analyze patient data, for example, tools to reconstruct a 3D model of the teeth. For example, using the browser, the treating professional can request the server 106 to animate the progress of the treatment plan. When the treating professional arrives at a prescription or other final designation, the treatment prescription is used to automatically generate appliances, as described in more details below. Further, in addition to aiding professionals in treating patients, the treating professional can perform office management, purchasing and other logistical operations using the browser and the dental server 106.

In addition to communicating with patients and treating professionals, the dental server 106 can communicate with one or more partners 110 using the network 102. The partners 110 can be product suppliers, service providers, or any suitable commercial entities.

One partner 110 can be a financing partner that offers customers with one or more electronic financing options. In one implementation, the financing partner can be a credit card processing company. The credit card processing company can accept a customer's

existing credit card or can issue the customer with a new credit card. Further, the credit card can be issued under the name of a third-party bank, the name of the credit card processing company, or the name of the site supported by the dental server 106 under a co-branding arrangement.

The customer enters the sensitive data such as credit card number, shipping address, among others, onto a purchase form. The credit data is then submitted, collected and passed securely through the dental server 106. This data can be processed in real time or can be collected by mail or telephone and then entered by an operator. A processor at the credit card processing company then verifies that the credit card number is valid and is not stolen, among other anti-fraud measures. If the credit card information is valid, the purchase price will be reserved from the issuing bank of the consumer's credit card and allocated to the account associated with the server 106. Periodically, the credit card processor settles all accounts; it is at this time that all monies move. Funds reserved are transmitted from the issuing bank of the cardholder's credit card to the account of the server 106. Also, discount fees are paid from these funds, as they are moving.

Alternatively, the financing partner can debit from the customer's checking account over the Internet. One such check debiting services is the MerchanTrust™ Paperless Checks™ Services, available from Merchant Commerce, Inc. These services provide customers with the convenience of making online purchases by checking account debits, with no manual data entry required of a merchant. In this embodiment, a customer fills in a form at the site with bank information printed at the bottom of his or her personal check. The information is processed as an Electronic Funds Transfer (EFT) to the customer's account using the Automated Clearinghouse (ACH) payment system.

Yet another possible partner 110 is a dental supply retailer providing an on-line shop on the web site to retail dental products to the customers and treating professionals. The retailer can be a co-branding partner that uses the brand name linked or suitably associated with the web site of the server 106 such that users of the server 106 would not know that the on-line shop is actually operated by a third party. The retailer can offer dental products for brushing, flossing, and cleaning of dental implants and bridges. Other dental products include anti-plaque rinse and plaque-fighting toothpaste. The retailer can also sell other health-care-related products such as prescription drugs; non- prescription drugs; personal care; beauty and spa; vitamins, herbs and nutrition; and medical supplies. Additionally, the retailer can serve the needs of the treating professionals by offering products such as brackets, buccal tubes, bands, archwire products, bonding adhesives, hand instruments, systems, supplies and equipment.

Yet another partner 110 can be a shipping partner. The shipping partner delivers dental supply or goods received from a multiplicity of producers and manufacturers for ultimate distribution to each customer. The facilities for warehousing and introduction of goods into a transportation stream for redistribution are the so-called cross docking facilities. The supply or good flows in bulk from a producer or a manufacturer to one or more cross docking facilities owned by either the shipping partner or the operator of the server 106. The items are then be broken into smaller unit sizes and distributed to the customers.

The above list of partners lists only exemplary partners and is not an exhaustive list. Other possible partners include value-added service providers such as third party

software providers who provide plug-in viewing and diagnostic enhancements that can be used by the professionals.

The server 106 can perform dynamic targeting and information gathering. The users provide demographic information when they register for our service. The server 106 can track our users' behavior the entire time they are online. As a result, the server 106 can deliver targeted advertisements and measure their effectiveness. For example, users can receive ads from a brokerage firm when they are viewing sites containing stock quotes or financial news, or receive promotions from a bookseller when browsing sites containing book reviews. As such, the dental server 106 can provide a prominent and sustained advertising medium to the community. In contrast to most portal and content sites which display advertising, the site remains with users the entire time they are online. Once users are logged on, the site remains in full view throughout the session, including when they are waiting for pages to download, navigating the Internet and even engaging in non-browsing activities such as sending or receiving e-mail. The constant visibility of the site allows advertisements to be displayed for a specified period of time.

In combination, the dental server 106 forms a hub that links dental clients using client computers 104-105, treating professionals using workstations 108-109, and partners 110 into a living electronic commerce (e-commerce) community.

Fig. 2 shows an embodiment of the server 106. The server 106 includes a web server 140, a patient information server 142, a resource planning (RP) server 144 and a streaming server 146. In one embodiment, the RP server 144 runs Microsoft SQL server and provides information relating to a doctor or a patient such as address and history. When a patient's case or static snapshots of the case is needed, the data is pulled from the

patient information server 142. When media data such as video needs to be streamed to a requesting client, the streaming server 146 can send the stream. In one implementation, the streaming data is stored in QuickTime format on a Linux-based server running the QuickTime server software.

The servers can be clustered. In one embodiment using Microsoft's Cluster Server, cluster-enabled applications such as Microsoft's SQL Server and Exchange. With Cluster Server, two servers can run applications at the same time. When one server fails, the remaining server handles its application as well as the failed server's applications. Next, the remaining server adopts the IP address of the failed server and mounts one or more data drives that the two systems share. The remaining server is rebooted and applications such as SQL Server can be started and initialized on this server. Persistent clients can re-attach to the server and continue to operate.

Referring now to Fig. 3, a diagram 200 shows various major functions supported by the dental server 106. First, the process 200 performs an automatic detection for the existence of a browser welcome plug-in (step 202). If the welcome plug-in exists, an introductory animation (flash) is shown (step 204). From step 204 or 206, the process 200 shows a home page (step 208) with one or more links. A link is created by having a word in a text field (or a graphic image on a web page) linked to the location of another web page, via a string of information setting forth the new web page address presented in hypertext transfer protocol (HTTP), among others.

The user can navigate the home page to join a particular site from a constellation of related sites. For instance, the user can navigate to a patient's site (step 208), a doctor's site (step 210), a privacy statement site (step 212), one or more additional sites

(step 214), and an about site (step 216), among others. The additional sites can be an on-line shopping store that is co-branded with the web site hosted by the server 106, or the on-line shopping store can be directly affiliated with a third party such as planet-rx.com, among others. The additional sites can also be third party value-added providers of products and/or services.

Fig. 4 illustrates an exemplary usage of the system of Fig. 1 from a patient's perspective. First, a prospective client using a client computer 104 visits the web site on the dental server 106 and identifies a treating professional meeting one or more criteria, for example a professional whose location is closest to his or her home address (step 230). Next, the patient schedules an appointment with the treating professional (step 232). At the meeting, an assistant captures various anatomical data from the patient by taking digital photographs of the face and teeth, taking x-rays of the front, back, side, and top/bottom of the patient, taking one or more impressions, among others (step 234). Next, this information is entered into a form on the server 106 (step 236). The data is then digitized, stored on the server 106, and made available to the treating professionals and the patient over the Internet (step 238). Next, the server 106 and one or more orthodontic treating persons process the patient data and render the patient's teeth in a plurality of alternative final states (step 240). Based on the choices, the patient selects a desired final state (step 242).

In addition to performing orthodontic operations, the server 106 can also perform other value-added services. For example, processes executed by the server 106 can simulate the color of the patient's enamel and show the color of the teeth before and after bleaching (step 244). Further, processes on the server 106 can simulate the color of the

patient's silver fillings (amalgram) and show the teeth after cosmetic work to cover the amalgam (step 246). After visualizing the effects of the operations, comparing the before and after operations, and reviewing guideline pricing for the orthodontic operation as well as add-ons such as bleaching (step 248), the patient makes a decision (step 250).

Once the patient has accepted a particular treatment selection, the server 106 offers the patient with one or more financing options from one of its financial partners (step 256). Additionally, the server 106 can guide the patient to an on-line shopping store to purchase products relating to his or her dental health (step 258). For example, the patient can buy cleaning supplies, brushes, and flossing supply at a price competitive to his or her traditional stores. Moreover, the products can be delivered to the patient using one or more delivery partners at a convenient time (step 260).

Figs. 5 and 6
~~Fig. 4~~ illustrates an exemplary usage of the system of Fig. 1 from a treating professional's perspective. A prospective patient uses a client computer 104 and visits the web site on the dental server 106 (step 280). The client identifies a treating professional and schedules an appointment with the treating professional (step 281). Alternatively, a referring dentist can refer the client to the treating orthodontist (step 282). The referring dentist can visit the web site on the dental server 106 and uses one or more dental esthetic tools to show patients the potential benefits of anterior and posterior esthetic restorations and, if the patient is interested, refers the patient to the treating professional (step 283).

During an initial examination, the treating professional or an assistant takes a set of digital facial and intraoral images which is uploaded to a secure, collaborative

workspace on the dental server 106 (step 284). The workspace is shared with the referring dentist.

Next, the treating professional generates a dentofacial treatment visualization showing the patient's face and smile before and after treatment (step 286). The treating professional can also combine the patient's face and an aligner into the intraoral image to show how the inconspicuous the appliance will be (step 288).

Once the patient requests treatment, the treating professional takes impressions and a bite registration and sends the information to the company (step 290). The treating professional also takes a lateral ceph and a panorex and uploads them and a treating prescription to the workspace (step 292). The professional's assistant creates a separate workspace for the patient, uploads selected "before and after" images into it, and invites the patient to review the images (step 294).

At the company, another professional reviews the records and decides to accept or decline the case (step 296). The models are then scanned, and the intraoral images are retrieved and used to texture-map enamel and gingiva (step 298). The data is then sent to the workspace and the treating professional is notified (step 300).

In one embodiment, the tooth models may be posted on a hypertext transfer protocol (http) web site for limited access by the corresponding patients and treating clinicians. Since realistic models have a large volume of data, the storage and transmission of the models can be expensive and time consuming. To reduce transmission problems arising from the large size of the 3D model, in one embodiment, data associated with the model is compressed. The compression is done by modeling the teeth meshes as a curve network before transmission to the treating professional. Once

the curve network is received, the 3D model is reconstructed from the curve network for the treating professional to analyze. More information on the compression is disclosed in a co-pending application having Serial No. _____ , entitled, "EFFICIENT DATA REPRESENTATION OF TEETH MODEL", and filed by ELENA PAVLOVSKAIA and HUAFENG WEN on February 17, 2000, the contents of which are hereby incorporated.

The treating professional can, at his or her convenience, check the setup, and review the information sent in step 300 (step 302). The treating professionals can use a variety of tools to interpret patient information. For example, the treating professional can retrieve and analyze patient information through a reconstructed 3D model of the patient's teeth and other anatomical structures. The professional can view animations showing the progress of the treatment plan to help the treating physician visualize the pace of treatment. Using these tools, the treating professional can easily and quickly view and/or edit the treatment plan.

If necessary, the treating professional can adjust one or more teeth positions at various intermediate stages of treatment (step 302). A variety of diagnostic decision-support capabilities such as automated teeth collision detection can be used to aid the treating professional in adjusting the teeth positions.

When the treating professional arrives at a prescription or other final designation, the treatment information is automatically collected by the system over the Internet, thus eliminating the cost and delay associated with the traditional physical shipping of patient information (step 304). These modifications are then retrofitted onto the dataset used to generate the aligners (step 306).

Fig. 3 shows a process 400 associated with a viewer that allows the treating professional to visualize the patient's teeth over the network 102 such as the Internet. In one embodiment, during start-up, a browser checks for a viewer plug-in module embodying the process 400 in a "plugins" subdirectory (Windows) or Plug-ins folder (Mac OS) in the same folder or directory as the browser (step 402). If the viewer plug-in module is available, the browser looks for a MIME type and extension info from the version resource. Through a TYPE attribute, the browser knows the MIME type and can load a registered plug-in first and, if there are no matches for the MIME type, the browser looks for a helper application.

Once the viewer plug-in is identified, the browser loads the viewer plug-in code into memory (step 404); initializes the viewer plug-in (step 406); and creates a new instance of the viewer plug-in (step 408). When the professional leaves the site or closes the window, the viewer plug-in instance is deleted. When the last instance of the viewer plug-in is deleted, the plug-in code is unloaded from memory.

Next, data files are downloaded to the viewer plug-in (step 410). In one implementation, the viewer plug-in downloads a data file from the dental server 102 using a suitable protocol such as a file transfer protocol (FTP). The viewer plug-in uses the downloaded file to present the treatment plan graphically to the clinician. The viewer plug-in also can be used by the treatment plan designer at the host site to view images of a patient's teeth. Fig. 4 shows an exemplary user interface for the viewer plug-in of Fig. 3. The professional can change views, select a particular tooth and change its position as desired (step 412).

3-D images of various orthodontic views can then be rendered after each instruction from the treating professional is received (step 414). In this process, an origin point, or "look from" point associated with a camera view is generated. Next, a "look at" point or a focus point associated with the camera view is determined. In this system, the line from LookFromPoint to LookAtPoint defines the direction the camera is shooting at. Additionally, a camera Z vector, or up vector, is determined.

Exemplary pseudo code implementations for generating various orthodontic views is shown below. With reference to the pseudo code, the code defines a bounding box of one mold (2 arches) which is the smallest cube containing the molds geometry. Other settings associated with the bounding box include:

Z_Axis: point from lower to upper,

Y_Axis: point from inside mouse to front teeth (incisors)

X_Axis: point from center to left.

FieldOfView: is the open angle, it corresponding to lens

HalfFieldOfView: FieldOfView * 0.5

MoldCenter: Center of the BoundingBox

X_Length: BoundingBox X dimension

Y_Length: BoundingBox X dimension

Z_Length: BoundingBox X dimension

X_MIN: minimum X value of the BoundingBox i.e. right most surface cube X value.

X_MAX: maximum X value of the BoundingBox

Y_MIN: minimum Y value of the BoundingBox

Y_MAX: maximum Y value of the BoundingBox

Z_MIN: minimum Z value of the BoundingBox

Z_MAX: maximum Z value of the BoundingBox

RIGHT BUCCAL OVERJET VIEW PSEUDO-CODE

CameraLookFromPoint:

X = 0.5 * MoldCenter.X + 0.5 * X_Max + 0.25 * MAX(Y_Length, Z_Length) / tan(HalfFieldOfView);

Y = MoldCenter.Y

Z = MoldCenter.Z – 0.25 * MAX(Y_Length, Z_Length) / tan(HalfFieldOf View);

CameraLookAtPoint:

X = MoldCenter.X + 0.25 * X_Length;

Y = MoldCenter.Y;

Z = MoldCenter.Z;

CameraUpVector: ZAxis;

ANTERIOR OVERJET VIEW PSEUDO-CODE

CameraLookFromPoint:

X = MoldCenter.X;

Y = 0.5 * MoldCenter.Y + 0.5 * Y_Max + 0.25 * MAX(X_Length, Z_Length) / tan(HalfFieldOfView);

Z = MoldCenter.Z – 0.25 * MAX(X_Length, Z_Length) / tan(HalfFieldOf View);

CameraLookAtPoint:

X = MoldCenter.X;

Y = MoldCenter.Y + 0.25 * Y_Length;

Z = MoldCenter.Z;

CameraUpVector: ZAxis;

LEFT BUCCAL OVERJET VIEW PSEUDO-CODE

CameraLookFromPoint:

X = 0.5 * MoldCenter.X + 0.5 * X_Min - 0.25 * MAX(Y_Length, Z_Length) / tan(HalfFieldOfView);

Y = MoldCenter.Y;

Z = MoldCenter.Z – 0.25 * MAX(Y_Length, Z_Length) / tan(HalfFieldOf View);

CameraLookAtPoint:

X = MoldCenter.X - 0.25 * X_Length;

Y = MoldCenter.Y;

Z = MoldCenter.Z;

CameraUpVector: ZAxis;

LEFT DISTAL_MOLAR

CameraLookFromPoint:

X = MoldCenter.X - 0.25 * X_Length;

Y = Y_Min – 0.25 * MAX(X_Length, Z_Length) / tan(HalfFieldOfView);

Z = MoldCenter.Z;

CameraLookAtPoint:

X = MoldCenter.X - 0.25 * X_Length;

Y = MoldCenter.Y;

Z = MoldCenter.Z;

CameraUpVector: ZAxis;

LEFT LINGUAL VIEW PSEUDO-CODE

CameraLookFromPoint:

X = MoldCenter.X + 0.125 * X_Length;

Y = MoldCenter.Y;

Z = MoldCenter.Z;

CameraLookAtPoint:

X = MoldCenter.X - 0.25 * X_Length;

Y = MoldCenter.Y;

Z = MoldCenter.Z;

CameraUpVector: ZAxis;

LINGUAL INCISOR VIEW PSEUDO-CODE

CameraLookFromPoint:

X = MoldCenter.X;

Y = MoldCenter.Y;

Z = MoldCenter.Z;

CameraLookAtPoint:

X = MoldCenter.X;

Y = MoldCenter.Y + 0.25 * Y_Length;

Z = MoldCenter.Z;

CameraUpVector: ZAxis;

RIGHT LINGUAL VIEW PSEUDO-CODE

CameraLookFromPoint:

X = MoldCenter.X + 0.125 * X_Length;

Y = MoldCenter.Y;

Z = MoldCenter.Z;

CameraLookAtPoint:

X = MoldCenter.X + 0.25 * X_Length;

Y = MoldCenter.Y;

Z = MoldCenter.Z

CameraUpVector: ZAxis;

RIGHT DISTAL MOLAR VIEW PSEUDO-CODE

CameraLookFromPoint:

X = MoldCenter.X + 0.25 * X_Length;

Y = Y_MIN – 0.25 * MAX(X_Length, Z_Length) /

tan(HalfFieldOfView);

Z = MoldCenter.Z;

CameraLookAtPoint:

X = MoldCenter.X + 0.25 * X_Length;

Y = MoldCenter.Y;

Z = MoldCenter.Z;

CameraUpVector: ZAxis;

Once the intermediate and final data sets have been created, the appliances may be fabricated as illustrated in FIG. 9. Common fabrication methods employ a rapid prototyping device 501 such as a stereolithography machine. A particularly suitable rapid prototyping machine is Model SLA-250/50 available from 3D System, Valencia, California. The rapid prototyping machine 501 selectively hardens a liquid or other non-hardened resin into a three-dimensional structure which can be separated from the remaining non-hardened resin, washed, and used either directly as the appliance or indirectly as a mold for producing the appliance. The prototyping machine 501 receives the individual digital data sets and produces one structure corresponding to each of the desired appliances. Generally, because the rapid prototyping machine 501 may utilize a resin having non-optimum mechanical properties and which may not be generally acceptable for patient use, the prototyping machine typically is used to produce molds which are, in effect, positive tooth models of each successive stage of the treatment. After the positive models are prepared, a conventional pressure or vacuum molding

machine ~~251~~ 551 is used to produce the appliances from a more suitable material, such as 0.03 inch thermal forming dental material, available from Tru-Tain Plastics, Rochester, Minnesota 55902. Suitable pressure molding equipment is available under the trade name BIOSTAR from Great Lakes Orthodontics, Ltd., Tonawanda, New York 14150. The molding machine ~~251~~ 551 produces each of the appliances directly from the positive tooth model and the desired material. Suitable vacuum molding machines are available from Raintree Essix, Inc.

After production, the appliances can be supplied to the treating professional all at one time. The appliances are marked in some manner, typically by sequential numbering directly on the appliances or on tags, pouches, or other items which are affixed to or which enclose each appliance, to indicate their order of use. Optionally, written instructions may accompany the system which set forth that the patient is to wear the individual appliances in the order marked on the appliances or elsewhere in the packaging. Use of the appliances in such a manner will reposition the patient's teeth progressively toward the final tooth arrangement.

Because a patient's teeth may respond differently than originally expected, the treating clinician may wish to evaluate the patient's progress during the course of treatment. The system can also do this automatically, starting from the newly-measured in-course dentition. If the patient's teeth do not progress as planned, the clinician can revise the treatment plan as necessary to bring the patient's treatment back on course or to design an alternative treatment plan. The clinician may provide comments, oral or written, for use in revising the treatment plan. The clinician also can form another set of plaster castings of the patient's teeth for digital imaging and manipulation. The clinician

may wish to limit initial aligner production to only a few aligners, delaying production on subsequent aligners until the patient's progress has been evaluated.

FIG. 10 is a simplified block diagram of a data processing system 600 that may be used to develop orthodontic treatment plans. The data processing system 600 typically includes at least one processor 602 that communicates with a number of peripheral devices via bus subsystem 604. These peripheral devices typically include a storage subsystem 606 (memory subsystem 608 and file storage subsystem 614), a set of user interface input and output devices 618, and an interface to outside networks 616, including the public switched telephone network. This interface is shown schematically as "Modems and Network Interface" block 616, and is coupled to corresponding interface devices in other data processing systems via communication network interface 624. Data processing system 600 could be a terminal or a low-end personal computer or a high-end personal computer, workstation or mainframe.

The user interface input devices typically include a keyboard and may further include a pointing device and a scanner. The pointing device may be an indirect pointing device such as a mouse, trackball, touchpad, or graphics tablet, or a direct pointing device such as a touchscreen incorporated into the display, or a three dimensional pointing device, such as the gyroscopic pointing device described in U.S. Patent 5,440,326, other types of user interface input devices, such as voice recognition systems, can also be used. User interface output devices typically include a printer and a display subsystem, which includes a display controller and a display device coupled to the controller. The display device may be a cathode ray tube (CRT), a flat-panel device such as a liquid crystal

display (LCD), or a projection device. The display subsystem may also provide non-visual display such as audio output.

Storage subsystem 306 maintains the basic required programming and data constructs. The program modules discussed above are typically stored in storage subsystem 306. Storage subsystem 306 typically comprises memory subsystem 308 and file storage subsystem 314.

Memory subsystem 308 typically includes a number of memories including a main random access memory (RAM) 310 for storage of instructions and data during program execution and a read only memory (ROM) 312 in which fixed instructions are stored. In the case of Macintosh-compatible personal computers the ROM would include portions of the operating system; in the case of IBM-compatible personal computers, this would include the BIOS (basic input/output system).

File storage subsystem 314 provides persistent (non-volatile) storage for program and data files, and typically includes at least one hard disk drive and at least one floppy disk drive (with associated removable media). There may also be other devices such as a CD-ROM drive and optical drives (all with their associated removable media). Additionally, the system may include drives of the type with removable media cartridges. The removable media cartridges may, for example be hard disk cartridges, such as those marketed by Syquest and others, and flexible disk cartridges, such as those marketed by Iomega. One or more of the drives may be located at a remote location, such as in a server on a local area network or at a site on the Internet's World Wide Web.

In this context, the term "bus subsystem" is used generically so as to include any mechanism for letting the various components and subsystems communicate with each

other as intended. With the exception of the input devices and the display, the other components need not be at the same physical location. Thus, for example, portions of the file storage system could be connected via various local-area or wide-area network media, including telephone lines. Similarly, the input devices and display need not be at the same location as the processor, although it is anticipated that personal computers and workstations typically will be used.

Bus subsystem 304 is shown schematically as a single bus, but a typical system has a number of buses such as a local bus and one or more expansion buses (e.g., ADB, SCSI, ISA, EISA, MCA, NuBus, or PCI), as well as serial and parallel ports. Network connections are usually established through a device such as a network adapter on one of these expansion buses or a modem on a serial port. The client computer may be a desktop system or a portable system.

Scanner ~~320~~ 620 is responsible for scanning casts of the patient's teeth obtained either from the patient or from an orthodontist and providing the scanned digital data set information to data processing system ~~300~~ 600 for further processing. In a distributed environment, scanner ~~320~~ 620 may be located at a remote location and communicate scanned digital data set information to data processing system ~~300~~ 600 via network interface ~~324~~ 624. Fabrication machine ~~322~~ 622 fabricates dental appliances based on intermediate and final data set information received from data processing system ~~300~~ 600. In a distributed environment, fabrication machine ~~322~~ 622 may be located at a remote location and receive data set information from data processing system ~~300~~ 600 via network interface ~~324~~ 624.

The invention has been described in terms of particular embodiments. Other embodiments are within the scope of the following claims. For example, the three-

dimensional scanning techniques described above may be used to analyze material characteristics, such as shrinkage and expansion, of the materials that form the tooth castings and the aligners. Also, the 3D tooth models and the graphical interface described above may be used to assist clinicians that treat patients with conventional braces or other conventional orthodontic appliances, in which case the constraints applied to tooth movement would be modified accordingly.